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A conceptual framework for a dyadic supplier-customer co-innovation of bioplastic packaging

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ABSTRACT

This paper unravels critical and imminent issues in co-innovation of bioplastic packaging. The current state of bioplastic packaging signifies the challenges caused by the mismatch of the characteristics of bioplastic packaging and the products they are intended for, and confirms the needs for a supplier-customer co-innovation. Although co-innovation, to a large extent, demonstrates immense potentials in promoting product improvement and environmental benefits, co-innovation in bioplastic packaging has not been extensively studied. This paper offers the processes and mechanisms of co-innovation in the form of a conceptual framework, detailing the joint activities and joint resources that address the specific bioplastic packaging characteristics.

1. Introduction

Bioplastics are considered to be an ideal substitute for certain types of conventional plastic packaging (Khan et al., 2017) because petroleum-based plastics leave solid waste material, creating serious global environmental problems. Bioplastics have more advantages compared to the conventional plastics as they are derived from plants, other biomass, microbial fermentation or chemical synthesis (Khan et al., 2017); and/or can be broken down by micro-organisms (biodegradable) (Verghese and Lewis, 2007).

Despite the increased sustainability awareness, market demand and regulation related to the plastic use, the development of bioplastic packaging industry is still at an early stage. One of the barriers is the downsides of bioplastics performance when applied to a wide variety of packaging. For example, barrier properties of a particular bioplastic packaging, which are critical to protecting food products from the external environment, often fall under the conventional plastics (Benetto et al., 2015). Therefore, this type of packaging is less suitable for food and fresh produce as its contents will quickly dry from evaporation and thus causing a shorter product shelf life (Khan et al., 2017).

In order to improve the usability of the bioplastic packaging, collaboration between the bioplastic packaging manufacturer and the product manufacturer is crucial. This collaboration will enable improvement of product functionalities (Morgado, 2008, Slater, 2010), add eco-friendly recognition to the final product and potentially reduce the cost of production (de Vargas Mores et al., 2018).

In this paper, the supplier-customer collaboration in bioplastic packaging product development refers to as the concept of co-innovation, as new ideas or approaches from various internal and external sources are synergised to create new value for customers or other stakeholders (Baldwin and von Hippel, 2011). The core of co-innovation includes convergence, a collaboration of ideas, actions and resources to create value that is difficult to imitate by competitors (Bitzer and Bijman, 2015). The term 'supplier' refers to as the packaging manufacturer, and 'customer' refers to as the product manufacturer, following the packaging supply chain (Verghese and Lewis, 2007).

This paper specifically aims to provide answers to the following questions: To what extent has co-innovation been studied in the context of bioplastic packaging product innovation? What are the mechanisms co-innovation? What are the outcomes of co-innovation? The next sections describe the research methodology, analysis, and synthesis of the conceptual framework that can be used as a theoretical lens to guide our future research.

2. Methodology

The systematic literature review (SLR) has been chosen as the research method as it provides a clear mechanism and a stringent data collection protocol, which minimises researcher's bias.

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The SLR method in this study comprises data collection, data analysis and synthesis (Tranfield et al., 2003).

Data collection was conducted based on a pre-determined search strategy, which included the application of the relevant keywords and search terms to selected databases. The initial search retrieved 1,440 articles from Business Source Complete (EBSCO), ABI/INFORM (ProQuest), Scopus, ScienceDirect, and Emerald.

These articles were then filtered based on the title, abstract and full-text, using the inclusion criteria that prioritised the purpose, findings and implications, relevant to the context of this study and, answered the research questions (Lusiantoro et al., 2018).

Thematic analysis (Braun and Clarke, 2006) was adopted to identify, analyse and report themes from the 58 articles selected. The interpretative approach was used to code and extract data from the collection and identify consensus or emerging themes (Tranfield et al., 2003).

3. Analysis

In general, the co-innovation for product development exists mostly between customers and suppliers (Baraldi et al., 2014; Farrow et al., 2000). The area of the collaboration comprises R&D (Jeong and Ko, 2016) and new product development (Theinsathid et al., 2009). The timing of co-innovation also crucial, in which the early stage co-innovation potentially increases the success of product development (Theinsathid et al., 2009).

3.1. Co-innovation in practice

Several studies exemplify a specific inter-firm collaboration in bioplastic that could be referred to as co-innovation best practices. First, a case study (Chadha, 2011) explained how the raw material and plastic packaging manufacturers, which initially did not have expertise in bioplastic technology, then were able to overcome competence lock-in and expanded to bioplastic through co-innovation with their supply-chain partners. The mechanisms that can be learnt from the cases that successfully delivered radical bioplastic innovation are: first, selecting a co-innovation partner who has expertise in bioplastic technology; second, establishing an independent project house that given authority to make budgets, decisions, policies, and located separately from the parent company; third, applying monitoring technology towards potential technical opportunities or threats, followed by determining initiatives that eventually accommodated in corporate planning. Next, they then intensified the R&D collaboration, for example, the supplier's engineers frequently visited the customer sites to learn about its needs, and offered problem-solving. Customers were invited by the suppliers to conduct a series of bioplastics tests.

Another example is the co-innovation of a successful petrochemical company in Brazil, that has now expanded to bioplastic (de Vargas Mores et al., 2018). Co-innovation was conducted with sugarcane planters, plastic manufacturers and downstream users; emphasising investment in R&D and the importance of R&D collaboration with universities and research institutions in product development (de Vargas Mores et al., 2018). This study also explained that co-innovation successfully added value to the final product by creating green products and reducing the production cost (de Vargas Mores et al., 2018).

Specifically, for bioplastics co-innovation, learning, exchanging knowledge and absorbing partners' capability occur bi-directionally. This is exemplified when the bioplastic manufacturers learn about the customers' needs and the customers learn about bioplastic technology (Jeong and Ko, 2016). However, detailed discussion on the process of co-innovation in product development, and particular bioplastic packaging are lacking because most of the study in the bioplastic context use data from secondary sources (Jeong and Ko, 2016).

Best practices in co-innovation for bioplastic packaging could be inferred from the packaging manufacturing industry. The mechanism of co-innovation in packaging industry often involves customers at the product development stage, and takes place at the customer's production site; all of which helps the supplier obtain a better understanding of customer's manufacturing processes and gain a closer access to the customer's operations (Morgado, 2008; Baraldi et al., 2014). However, in this setting, it was reported that the supplier acts as a business consultant, often insisting the customer to share confidential information on the sales and user complaints (Morgado, 2008, Slater, 2010, Baraldi et al., 2014). Learning from the success of co-innovation packaging to enhance the quality of product performance for users is critical to address the challenges in the application of bioplastic packaging. Table 1 presents a summary of best practice co-innovation in packaging and bioplastics. Nonetheless, this area is relatively under-explored, thus become a research gap.

3.2. Themes regarding the co-innovation mechanisms

There are three themes emerging from the analysis: *joint activities*, *joint resources* and the *relationship management*.

Joint activities represent the supplier-customer interactive, reciprocal, pro-active activities, by integrating sustainability principles (Chen et al., 2017), aiming to support the customer's innovation (Farrow et al., 2000). These activities are mainly related to transfer knowledge, which is achieved through continuous learning, knowledge sharing and exploration of new knowledge. Continuous learning includes assimilation of diverse knowledge to innovate and development of novel technology (Chadha, 2011). The customer and supplier share information and knowledge in order to explore new technologies, cutting edge manufacturing and product technologies (Dangelico, 2016). They also involve in R&D activities and learn specific technical needs and requirements (Chadha, 2011).

Joint resources comprise tangible and intangible resources dedicated by both supplier and customer beyond the transactional relationships. The resources shared in the sustainability product development context are environmental knowledge and technology (Dangelico, 2016; Melander, 2018). Additional joint investment often required in the product development project, such as infrastructure (Chen et al., 2017; Cheung et al., 2010), production unit (Morgado, 2008), research facilities and equipment, training on the environmental management and knowledge (de Medeiros and Duarte Ribeiro, 2013).

Relationship management represents efforts aiming to build a productive relationship before, during and after the co-innovation. Partner selection is an essential start for co-innovation for bioplastic packaging. A partner with innovative capability (Farrow et al., 2000), complementary skills in the environment or sustainable areas (Chadha, 2011) that possibly confirmed through environment audit or certification (Cheung et al., 2010), is highly valuable. Co-innovation will be productive when both supplier and customer are the problem solver type of partner that also highly concerned about environment or sustainability issues (Arnold, 2017). Co-innovation should be built within a strategically close relationship (Lee and Kim, 2011) towards a synergy to address problems in bioplastics instead of merely forced by regulations (Arnold, 2017).

The mechanisms of co-innovation in bioplastic packaging should encompass not only product improvement but also sustainability practices such as environmental and technological know-how, and sustainable processes throughout the value chain for better life-cycle assessment. However, further details are lacking in the existing studies.

Table 1
Co-innovation mechanism in packaging and bioplastics manufacturing

	Packaging	Bioplastics
Co-innovation mechanisms	involving the customer in product development, co-location to customer's site, sharing confidential information, provide services to support customer's business process: just in time delivery, HR training, ERP.	involving raw material producer, polymer, packaging and product manufacturer, also with government, universities or research institutions, establishing an independent project at a separate location to the main company, intensifying R&D collaboration: exploring new technology, numerous testing.
Outcomes	Improved packaging quality and performance, which also become a solution to customer's problems	New bioplastic material with lower environmental impact, improved certain material properties, but still some problems when applied to the product, lower cost of production but still more expensive than the conventional packaging.

Finally, the outcomes of co-innovation are indicated by the improved product quality and performance, lower production costs, enhanced the organisation's capability and performance, lower impact on the environment and higher environmental responsibility (Dangelico, 2016). Co-innovation in bioplastic packaging will promote the final product as an eco-friendly product (Farrow et al., 2000). Co-innovation enables efficient use of resources, thus lower the cost of production, lower the impacts on the environment, preventing waste generation at the conception stage. In the long term, the supplier capitalises its know-how in product development that induces a stronger interdependence with the customer (Baraldi et al., 2014).

4. The framework

This study reveals the underlying mechanisms of co-innovation for bioplastic packaging, of which stand on the inter-relationship among joint activities, joint resources and relationship management between the supplier and customer. Synergising internal and external ideas, actions and resources enable the creation of new value that is difficult to be imitated by competitors (Baldwin and von Hippel, 2011). In accordance with the *relational view theory* (Dyer and Singh, 1998) and the *absorptive capacity theory* (Zahra and George, 2002), co-innovation between customer and supplier is enabled by the integration of complementary resources and knowledge to create greater benefits: product innovation capability and innovative product (Cheung et al., 2010; Tavani et al., 2014), which cannot be achieved individually. In this context, the integration of complementary resources and knowledge are represented by the joint activities, joint resources and nurtured by the relationship management between the collaborating supplier and customer.

The urgency for co-innovation for bioplastic packaging product advancement is apparent. The packaging manufacturer, while having valuable expertise in bioplastics, often lacks an understanding of its application to the product and therefore cannot easily market the packaging products. On the other hand, product manufacturers will find it less feasible to manufacture the bioplastic packaging themselves due to lacking expertise in this field (Lee and Kim, 2011). By engaging in co-innovation, the supplier and customer will be able to enhance the resources and capabilities to overcome the problems in the application that many of their competitors cannot. The outcome of co-innovation in the form of an advanced bioplastic packaging, indicated by improved product quality, sustainability, cost and innovation, depicts the relational rent (Dyer and Singh, 1998) or greater benefit that cannot be achieved when each partner works individually.

The interactions of supplier and customer in the co-innovation are two ways, occurring in activities mainly related to learning from each other. Following the relational view, transfer knowledge and the creation of specialised knowledge will lead to a greater outcome or relational rent (Dyer and Singh, 1998). Likewise, the supplier-customer interaction directed towards innovation-oriented learning (Chadha, 2011; de Medeiros and Duarte Ribeiro, 2013) and sharing information; for example, the new bioplastics technology, application of packaging, desired function and features, knowledge about the industry and regulation. A certain degree of complementary information will build a new combined knowledge useful to product development success.

The following proposition would therefore represent the association of joint activities and performance:

Proposition 1. *The higher supplier-customer joint activities will deliver the greater bioplastic packaging product innovation.*

Bioplastic product development requires specific tangible and intangible resources, and for that, both customer and supplier allocate a specific investment beyond transactional (Dyer and Singh, 1998), for instance by providing location, sharing cost, cross-functional team, production unit (Baraldi et al., 2014; Morgado, 2008), HR training in environmental management (de Medeiros and Duarte Ribeiro, 2013), other infrastructures or establishing an exclusive product development project (Chen et al., 2017). Joint resources mechanism is exemplified as the customer utilises the supplier's resources and capabilities related to bioplastics or the sustainability field, such as environmental knowledge, technology (Dangelico, 2016; Lee and Kim, 2011; Melander, 2018), while the supplier uses the customer's production facilities (Morgado, 2008). Therefore, joint resources, especially the complementary resources and capabilities, will become a source of greater outcome (Dyer and Singh, 1998). This is postulated by the following proposition:

Proposition 2. The higher supplier-customer joint resources will deliver the greater bioplastic packaging product innovation.

Relationship management is essential for successful co-innovation. More attention should be made for partner selection, preferably the key suppliers and customers. Additionally, partner selection needs to consider the existence of complementary innovation capabilities, environmental skills and expertise (Farrow et al., 2000), which are confirmed through environment audit or certification (Cheung et al., 2010). A compatible partner, open communication, coordination, balanced task division and leading position (Lee and Kim, 2011), as well as moderated inter-organisation boundaries (Baraldi et al., 2014), will promote effective and pro-

Table 2
Key elements of bioplastics packaging co-innovation

Mechanism	Elements
Joint- activities	Routinised transfer knowledge: exploration of new bioplastic technology, new alternatives in the application, learn customer's manufacturing process, product features, health and safety, product storage, transport and delivery to the warehouse, store or end-user, in-store display Intensive R&D: involve direct users (packaging manufacturer/converter or product manufacturer) in the product development stage; conduct numerous tests in the user's real manufacturing/ product setting. Both partners improve and adjust iteratively: The bioplastic packaging manufacturer improves the crucial feature for the product manufacturer, The product manufacturer adjusts the requirement, willing to compromise less performance than the conventional plastic and find opportunities to maximise the bioplastics packaging distinct feature, for example: change the packaging colour/design, accentuate the "green plastic packaging" in the marketing campaign. Integrate sustainable principles in the operations
Joint resources	Access to customer's production site, trial in the real production settings, Supplier's expertise in bioplastic technology, environmental management, Share confidential detail information related to the application of the bioplastics packaging, for example, machine, manufacturing or technical requirement; product properties, health and safety requirement; product storage, logistics procedures. Build an independent shared-project: share cost, research facilities and team
Relationship management	Partner selection: supplier has expertise in bioplastic technology, has a certificate in sustainable practice, meet a certain standard in bioplastics, such as biodegradability, compostability, or other environmental regulation.

ductive activities, reconciliation and problem solving (Melander, 2018), therefore are likely to achieve bioplastic packaging product innovation success.

Proposition 3. The higher supplier-customer relationship management will deliver the greater bioplastic packaging product innovation.

Despite the positive impact towards the outcome of co-innovation, relationship management plays a vital role to support the joint activities and joint resources dedicated to the collaboration (Melander, 2018). Working with the right partner allows excellent communication and coordination, sharing knowledge and learning. Open communication and fluent coordination in day-to-day activities enable both consumer and supplier to build a stronger relationship that leads to a willingness to dedicate more resources to the collaboration.

Proposition 4. The higher relationship management will lead to the higher joint activities dedicated to co-innovation.

Proposition 5. The better relationship management will lead to the higher joint resources dedicated to the collaboration.

In the bioplastic packaging co-innovation, joint activities involve routinised learning, transfer knowledge and building new specialised knowledge. Successful learning requires the existence of absorptive capacity (Dyer and Singh, 1998) to achieve bioplastic packaging product innovation. The absorptive capacity for bioplastic packaging is indicated by the acquisition of new valuable knowledge, followed by assimilation, transformation and exploitation of knowledge (Zahra and George, 2002) from each partner.

Through joint activities and joint resources, each partner acquires valuable information (Zahra and George, 2002) about the new bioplastics technology industry, environmental regulation, packaging applications for the product, and the desired feature of the packaging. Subsequently, the knowledge sharing routines facilitate the assimilation of new knowledge as both supplier and customer build understanding based on a more diverse perspective from their co-innovation experiences. These understanding are then transformed into a new or more advanced knowledge that promotes customer and supplier solutions and adaptation. At the supplier's side, the adaptation such adjustment of the product design will likely occur after learning about the customer's needs (Baraldi et al., 2014). On the other hand, the customer might modify the product specification request to get align with the supplier's offering (Lacoste, 2016).

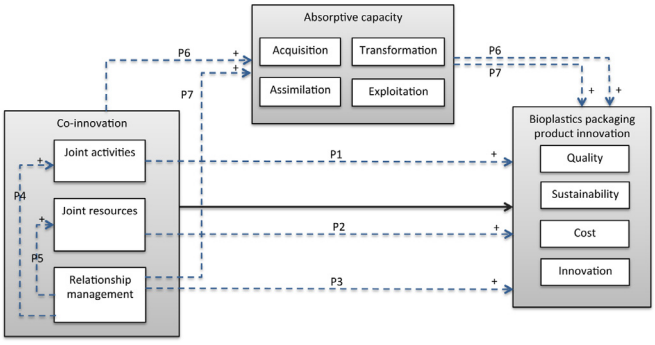

Fig. 1. Framework of co-innovation for bioplastic packaging product innovation

Correspondingly, the absorptive capacity strongly predicts the adoption of environmental innovation (Aboelmaged and Hashem, 2019), enriches the bioplastic packaging product design and accelerates the product development by minimising correction at the user testing stage, thus increases the success of bioplastic packaging product development. The outcome of co-innovation might only be achieved in the existence of absorptive capacity (Tavani et al., 2014).

Proposition 6. The relationship between co-innovation and bioplastic packaging product innovation is mediated by the absorptive capacity.

The absorptive capacity increases if a compatible partner, open communication, coordination and balanced relationship are higher in the co-innovation. The close relationship enables both collaborating partners to acquire information, learn and exploit new combined knowledge.

Proposition 7. The stronger relationship management will lead to the higher absorptive capacity, and therefore the *greater bioplastic packaging product innovation*.

Some specific joint activities, joint resources, relationship management, are proposed as the key elements of bioplastic packaging co-innovation mechanism, see Table 2. These specificities complement other co-innovation mechanisms, such as which has been implemented in different industries.

The proposed mechanism of the supplier-customer co-innovation for developing innovative bioplastics product is presented in Fig. 1.

5. Conclusions

The existing studies have revealed the importance of co-innovation in the development of bioplastic packaging with the supply chain members. However, the mechanisms of co-innovation have not been clearly presented.

This study provides a valuable contribution by identifying research gaps, and thus the needs for further research in bioplastic packaging co-innovation. Furthermore, this study discovered the co-innovation process and mechanisms through joint resources, joint activities and relationship management. Finally, the ideal outcomes of co-innovation are indicated by product quality, cost, sustainability, innovation.

The concept of co-innovation in the previous study (de Propris, 2002), which revealed joint activities and commitment to resources, as well as the significant impact to the creation of a new or improved product or process, is extended in this study by adding explicit mechanisms to implement joint activities and joint resources in practice, as shown in the proposed framework.

In addition, this study highlights the capabilities needed in co-innovation to create green product innovation, presented in the previous study (Melander, 2018), as *joint resources*; then shows the mechanism that contributes to strengthening these capabilities as well as how to work with these capabilities to achieve an advanced bioplastic packaging.

The framework proposed is synthesised from a literature review, therefore, more exploratory studies are needed to reveal the compatibility of the framework in the real-world settings. Due to limited discussion explicitly address bioplastic packaging co-innovation found in the existing studies, specific areas need further investigation, such as how joint activities, joint resources and relationship management work in practice. This will allow the elements of co-innovation in bioplastic packaging to be refined. Although some cases of bio-plastics co-innovation have been presented in this paper, the challenges that lead to failure in the implementation of co-innovation have not been clarified; thus, worthy to be given a special attention in future studies, as these will subsequently raise awareness amongst practitioners.

CRediT authorship contribution statement

Liliani: Conceptualization, Methodology, Investigation, Writing - review & editing. **Benny Tjahjono:** Conceptualization, Validation, Supervision, Writing - review & editing.

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